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AUTHOR Tedford, John R.
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ABSTRACT

A simple deterministic macroeconomic computer model was tested in a junior-senior level economic statistics course to demonstrate how and why some common errors arise when statistical estimation techniques are applied to economic relationships in empirical problematic situations. The computer model was treated as the true universe or real-world system, and each student was required to use it to generate his own sample data. The class experiment was successful in that few of the students were able to obtain by computer perfect statistical estimates, since most results possessed estimation errors similar to those found in empirical analysis. Weaknesses of the experiment are discussed, and the macroeconomic model and sample data generated by students are presented in figures. (CHV)

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USE OF A DETERMINISTIC MACROECONOMIC COMPUTER MODEL AS A TEACHING AID IN ECONOMIC STATISTICS

BY

John R. Tedford

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Use of a Deterministic Macroeconomic Computer Model as a Teaching Aid in Economic Statistics

John R. Tedford
School of Management
Clarkson College of Technology
Potsdam, New York 13676
(315) 268-6434

Introduction

The literature about developments in economics education over the past decade reveals a renewed interest in the never-ending search for new and better ways of improving the undergraduate learning process and the teaching of economics. Major emphasis, of late, has been directed at questions of methodology and at techniques which may be used in place of or as complementary aids to the traditional lecture approach. As one might expect, these developments are similar to those occurring in other subject-matter areas. Presumably improvements in the learning techniques for one area will have interdisciplinary benefits. In this sense it appears that some of Professor Bork's [1] general comments and hypotheses about the use of computers are as meaningful for the teaching of economics as they are for physics. He argues that the test of all learning is with students and the value of teaching materials, computer or otherwise, depends upon whether or not they lead to some type of learning for some students. In effect Bork, much like Kelley [5], suggests that the learning process is an individualistic or micro process. If we subscribe to this position and expect to be successful in improving upon our traditional teaching activities, a variety of techniques and instruments designed to meet the individual student's needs will be required.

The field of economics has seen an increasing number of new techniques developed and used over the past several years. Particular attention has been directed at the use of computerized macroeconomic models in the principle courses. Such models were often designed and used in the hope that students would obtain a better understanding about modern macroeconomic concepts and how they relate to questions of public policy. For example, Attiyeh [5] claims that students often cannot deal successfully with practical policy problems because they misunderstand the connection between economic analysis and its application to the real world. He states, "One way to counter this misunderstanding is to let students make concrete policy decisions on their own, using the Macroeconomic Policy game. . . .Consequently, (students) learn to carry out economic analysis and come to view it, not as an irrelevant logical exercise, but rather as the useful policy tool that it is."

In a discussion paper Bower [2] raises some important questions about the use of macroeconomic computer games as teaching experiments. He argues that while students have fun in playing computerized games, they may not learn much if not much is asked of them. He states, "They have fun and learn something when they set values for policy variables in an effort to achieve output, employment, and price targets. But wouldn't they learn a great deal more if they were forced to formulate their analysis, make their model explicit and provide numerical estimates of relevant relationships. . . With an explicit model and a derived table of multipliers, students should learn more from analysis than they ever could from errors such as confusing tax-income causality."

No doubt an experiment designed to have students obtain estimates of relevant struc-

tural parameters for an explicit model and to make policy decisions based upon them would provide a more complete and effective learning experience. One suspects, however, that such an experiment would be meaningful only for those students who had prior knowledge about model building and about statistical estimation techniques. These prerequisites are much greater than one could normally expect to find in undergraduate students taking a beginning macroeconomic principles course. They are topics one would normally expect to find covered in courses in economic statistics or econometrics. Presumably use of the above type of experiment would be more appropriate in such a course.

The Problem

The purpose of this paper is to describe how a simple deterministic macroeconomic computer model was used as an experiment in a junior-senior level economic statistics course. The objective of the experiment was to demonstrate how and why some of the errors commonly arise when statistical estimation techniques are applied to economic relationships in empirical problematic situations. The computer model was treated as the true universe or real-world system and each student was required to use it to generate his own sample data. The basic hypothesis underlying the experiment was—if students really understood (1) the underlying concepts and methods of statistical estimation of economic relationships, and (2) the reasons why the basic assumptions underlying these methods may be violated when applying them empirically, then they would make decisions in such a way that the resulting sample data and parameter estimates would be free of all estimation errors other than sample errors.

A deterministic macroeconomic computer model was designed and used to broaden the student's problem, in hopes that it would provide a better learning experience. The estimation of parameters for economic relationships by multiple regression or other techniques involves use of two models—one economic and the other probabilistic or statistical. Many of the empirical estimation errors arise because of differences or inconsistencies in or between these two models. That is, in applying statistical estimation techniques we generally assume that the specifications for the economic model and the available data satisfy the requirements and assumptions of the underlying statistical model. All too often some aspect of these models, as traditionally formulated and applied, will be violated. Due to differences between the hypothesized and actual conditions, a number of problems may arise. Accordingly, if the students were to obtain meaningful parameter estimates in the experimental situation, they would have to consider the relationships between the economic and statistical models. Use of a deterministic model as the true information generating mechanism compounded the problem because the students had to provide the random or stochastic elements consistent with the statistical model. That is, the students were expected to make decisions in a manner which explicitly generated data possessing the prerequisite random characteristics, or they would encounter such estimation errors as multicollinearity, autocorrelation, heteroskedasticity, or specification errors of various types, etc.

The Experiment

The overall class assignment may be looked upon as a set of estimation experiments. That is, each student's use of the computer model, as the true population mechanism, to generate sample data and to obtain parameter estimates constitutes an experiment. By varying the types and amounts of information made available to students about the model's specifications, initial conditions and/or computer print-out data, one can alter the structure of the experiments. As mentioned earlier, many of the estimation errors arise because the traditionally formulated economic and statistical models are applied in a world of less-than-complete or perfect knowledge. When the information and specifications provided by the instructor are not complete, the student is forced to provide his own a priori hypothesis and specifications which may or

may not be consistent with the true model's structural characteristics. Likewise, the student has to evaluate and analyze his computer-generated sample data in much the same way as he has to analyze real-world data. Either situation can be a source of estimation errors. One of the major advantages of this type of experiment is that each student's statistical estimates can be compared with the true parameter values. When discrepancies exist, the class can be called upon to evaluate each experiment's results and to provide an explanation of the types of errors and their possible causes.

The above framework was used with all students in the economic statistics class. The macroeconomic computer model was a revised version of one developed by Professor Attiyeh [5]. Each student was assigned an independent economy having the same parameter values and initial conditions. The instructions included: (1) a description of all of the relationships comprising the model, (2) definitions for each variable, (3) values for initial conditions of the system, (4) parameter values for all relationships other than the unemployment and the rate of inflation functions, and (5) the assigned problem or task. Since each student had prior experience and familiarity with statistical estimating programs on the computer, no information of this type was needed.

The specific assignment consisted of two parts. Each student was told to generate a sample of any size he wished but to use a sample of only twenty observations to obtain estimates for the parameters of the Phillips curve. Each student was also asked to keep a record of the decision rules and procedures he used in generating data and in obtaining parameter estimates.

The class discussed the concept of the Phillips curve and its use to reflect the trade-off between unemployment and inflation. No information was provided about the specific mathematical nature of the Phillips curve in the true model other than that provided in the model's description. Specifications for the Phillips curve may be obtained from the unemployment and rate of inflation relationships as given in Appendix A. Manipulation of these relationships indicates that the Phillips curve is given by three sets of relationships depending upon the state of the economy.

The first segment of the Phillips curve applies when the economy is running with inflationary pressures, i.e., equilibrium NNP > full employment NNP. In this case, unemployment (U) will equal a minimum value of 3 percent. Inflation, on the other hand, becomes larger and larger as the difference between the equilibrium value of NNP and the full employment value of NNP gets greater due to equation 16 in Appendix A. That is, the Phillips curve is given as

(1) $F = 306 - 700\,(Y'/Q) + 400\,(Y'/Q)^2$
when $U = 3$ and $Y' > Q$
where Y' is equilibrium *NNP* and Q is full employment *NNP*.

If, however, the economy experiences deflationary pressures, i.e., equilibrium *NNP* < full employment *NNP*, then unemployment will vary and be greater than 3 percent. The rate of inflation is generated by one of two relationships, equations 15 or 16, depending upon the ratio that equilibrium *NNP* is to the full employment value of *NNP*. Upon examining these relationships, we find that when unemployment U reaches its minimum value of 3 percent, the rate of inflation F approaches a value of 6 percent. On the other hand, F is zero when U is 5.8 percent and F takes on a negative value when U is greater than 5.8. When unemployment takes on values from 3 to 6 percent, the Phillips curve is obtained by manipulation equations 14 and 16 which yields

(2) $F = 21.28 - 6.62\,U + .51\,U^2$ for $3 \leq U < 6$.

Third, when unemployment is equal to or greater than 6 percent, the Phillips curve is linear because both equations 14 and 15 are linear. That is, the third segment of the Phillips curve is given as

(3) $F = -.069 - .0018\,U$ for $U \geq 6$.

The computer model was run on an IBM 360/44 under a batch mode. The students

received instructions about the procedure for making decisions. They were allowed one week as a trial period to familiarize themselves and to minimize procedural errors. Few restrictions were placed upon the students who could use any combination of three decision variables to manipulate their economy over time. Each could control movements in the equilibrium values of NNP over time by changing (1) government spending, (2) the rate of taxes, and/or (3) the money supply. The students were told several times that the macroeconomic computer model was deterministic, in hopes that they would explicitly consider and build a random process in their sample data when making their decisions.

Results and Conclusions

Few of the students were successful in obtaining perfect statistical estimates as most results possessed estimation errors similar to those one finds in empirical analysis. In this respect, the class experiment might be judged as having been successful.

Only the results for six of the students' experiments will be described. This is not a serious limitation, however, because the excluded results were basically similar to those which will be described. To simplify discussion, the six students' experiments have arbitrarily been designated by use of the first six Roman numerals.

The decision rule or procedure underlying each of the six students' sequence of decisions (i.e., each economy's time path for the decision variables) were as follows: (1) In Economy I no changes were made in any of the decision variables. That is ΔG, ΔTX and ΔMS were each set equal to zero during each quarterly time period. (2) Government spending was the only decision variable used in Economy II. The procedure was to make the change in government spending equal to any amount necessary to attain an unemployment rate of 4 to 5 percent in each time period. (3) The time path for the decision variables utilized in Economy III was similar to that in Economy II. An attempt was made to attain a zero level of inflation in each time period. (4) In Economy IV, both government spending and the money supply were changed in a random manner. Apparently the variance of the random process was not large because the changes made in the decision variables from period to period were small in value. (5) Government spending and the money supply were also altered in Economy V. The money supply was varied in a random manner but government spending was changed by an amount which the student expected would make the equilibrium value of *NNP* equal to 97 percent of full employment *NNP*. (6) In Economy VI the student randomly selected values for the independent variable *Y/Q* contained in unemployment and inflation equations in the model (Appendix A). The student only used government spending as a decision variable which he changed by an amount expected to yield the randomly generated value of *Y/Q* for each quarter.

Sample data for the variables *U* and *F* for each economy are given in Appendix B. Casual examination of these data suggests that the students assumed that the correct specification for the Phillips curve was but one relationship for all possible values of *U*. Because of this, it appears that specification errors might present some estimation problems in Economies I, IV, and VI. The data also suggest that problems of multicollinearity might be present in Economies II and III. Positive autocorrelation might be found in the statistical estimates for all economies, possibly with the exception of Economy VI.

Since no restrictions were placed upon the specific mathematical functions that the students could postulate, many types were specified and estimated. The estimation results are summarized in Table 1 for the linear and quadratic models as these were the only types of functions commonly used. Even though these results are partial and incomplete since they show the findings for only a part of the class, they do offer some interesting conclusions. They are interesting both with respect to their statistical characteristics and the objective of this paper.

Table 1. Students' Statistical Estimates for the Parameters of the Phillips Curve[1]

I. Linear Model: $F = a + b\,U + e$

Economy			
I	$F = 1.003 - .178\,U$ (− 625.)	$R^2 = 1.$	$D = 1.468$
II	$F = 8.591 - 1.535\,U$ (− 75.6)	$R^2 = .9969$	$D = .853$
III	$F = 2.795 - .472\,U$ (7.6)	$R^2 = .76$	$D = 2.09$
IV	$F = 40.67 - 7.08\,U$ (− 3.9)	$R^2 = .46$	$D = 0.50$
V	$F = 5.87 - .84\,U$ (− 9.2)	$R^2 = .83$	$D = 1.29$
VI	$F = 74.5 - 11.46\,U$ (− 1.7)	$R^2 = .14$	$D = .71$

II. Quadratic Model:[2] $F = a + b\,U + c\,U^2 + e$

Economy			
I	$F = 1.026 - .18\,U + .0002\,U^2$ (− 73.9) (1.88)	$R^2 = 1.$	$D = 1.887$
IV	$F = 101.9 - 35.58\,U + 3.1\,U^2$ (− 2.6) (2.12)	$R^2 = .57$	$D = .51$
V	$F = 18.0 - 5.26\,U + .37\,U^2$ (− 19.1) (16.1)	$R^2 = .989$	$D = 2.72$
VI	$F = 201.7 - 69.3\,U + 5.76\,U^2$ (− 1.02) (.85)	$R^2 = .17$	$D = .79$

1. The values in the parentheses under the coefficients in each equation are the values of students' *t* statistic.

2. No results were available for this model for Economies II or III and no explanation was provided.

Upon analyzing and comparing the statistical estimates and associated statistics for the linear models, one finds that the overall findings for Economy I yield the best results. This is what one might expect to obtain because all of the values for U in Economy I are greater than six, quite consistent with the linear specification for the third segment of the True Phillips curve. The observations for all other samples are inconsistent with the specifications for this segment of the Phillips curve. Accordingly, the statistical estimates for each of the economies other than I appear to have some type of estimation error. For example, while the parameter estimates for Economy III provide the next best set of results, they overestimate the true parameter values and the linear estimating model only explains about three-fourths of the error in the dependent variable F.

Statistical estimates for the quadratic models also vary considerably. The best estimates were obtained for Economy V. The sample data for this economy, while not perfect, are consistent with specifications for the second segment of the True Phillips curve. That is, if one were interested in policy decision over the relevant range of values of U between 3 and 6 percent, Economy V's estimates would provide reasonable approximations. This appears to be so even though the sample estimates underestimate the true parameter values and the test for negative autocorrelation is inconclusive. On the other hand, while the quadratic model explains all of the variations in inflation for Economy I, it is not significantly better than the linear model because the coefficient associated with the U^2 term is not significantly different from zero. The overall results for Economies IV and VI are not at all reasonable because of positive autocorrelation and other errors.

The above brief comments illustrate the nature of the discussion that took place in the

classroom after the students had handed in their respective findings. Upon receiving the students' findings, the true specifications for the Phillips curve were distributed. The students were then asked to describe the nature of the statistical estimation errors present in the findings and to explain why each error may have occurred. The students' analyses and explanations were not as rich nor as complete as had been hoped. Nevertheless, the overall results supported the contention that macroeconomic computer models can be effectively used in economics courses to teach about concepts and topics other than public policy.

All of the students appeared to enjoy knowing the true parameter values and being able to compare their results with the true values as well as the findings of others. They were all surprised at the variability in their results. While most of the students indicated that they understood the objective of the assignment, apparently several did not fully understand the complexity of their individual assignments. It was apparent in the class discussion that some of the students did not understand that when one uses a deterministic computer model, estimation errors are likely to arise if one does not explicitly look upon the use of the model as an information-generating mechanism and so use it to generate data that are of a random nature. The author believes that treatment of this aspect of the experiment was a major weakness.

Another apparent weakness of the experiment was that the design was far from perfect as there are several ways in which the class's experience could be improved upon. The problem assignment could have been more structured than it was. Much more specific information could have been given to the students and tests could have been used to determine if the students understood the problem and procedural aspects involved in its solution. Nevertheless, the author believes use of the computer model was effective and with appropriate modifications it will be even more effective as a teaching aid in the future.

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APPENDIX A

The Macroeconomic Model and Definitions for Variables

The Model

I. Potential full-employment *NNP*

(1) $A_t = (1 - a_1)A_{t-1}$

(2) $L_t = (1 - a_2)L_{t-1}$

(3) $K_t = K_{t-1} + a_3 I_{t-1}$

(4) $Q_t = A_t \cdot L_t^{a_4} \cdot K_t^{a_5}$

II. Commodity and money markets

(5) $C_t = b_1 + b_2 \cdot YD_t$

(6) $I_t = b_3 + b_4/(Q_t \cdot R_{t-1}) + b_5 Y_t + Z_{t-1}$

(7) $BS_t = b_6 Y_t$

(8) $G_t = G_{t-1} + \Delta G$

(9) $YD_t = Y_t - TX_t - BS_t$

(10) $TX_t = b_7 + b_8 Y_t$

(11) $MS_t = MS_{t-1} + \Delta MS$

(12) $R_t = b_9 + b_{10}(MS_t/P_{t-1}) + b_{11} Y_t$

(13) $Y_t = C_t + I_t + G_t$

III. Other relationships

(14) $U_t = 3 + 28(1 - Y_t/Q_t)$

(15) If Y_t/Q_t .89

$F_t = -.08 + .05(Y_t/Q_t - .89)$

(16) If Y_t/Q_t .89

$F_t = 306 - 700(Y_t/Q_t) + 400(Y_t/Q_t)^2$

(17) $Z_t = Z(Q_t, Y_t)$

(18) $P_t = P(F_t)$

(19) $W = W(C, I, G, U, F)$

Definitions

A — state of technology
L — labor force
K — capital stock
Q — full employment NNP
C — desired consumer spending
I — desired investment spending
BS — business savings
G — government spending
TX — government taxes
Y — NNP
YD — disposable income
MS — money supply
R — interest rate
U — percent unemployment
F — rate of inflation
P — price level
Z — inflationary inventory disinvestment factor
W — welfare index

APPENDIX B

Sample Data Generated by Students for Variables *U* and *F*

Economy I		*Economy II*		*Economy III*	
% Unemployment	Rate of Inflation	% Unemployment	Rate of Inflation	% Unemployment	Rate of Inflation
U	*F*	*U*	*F*	*U*	*F*
6.47	− .15	4.79	1.25	6.23	− .11
6.87	− .22	4.76	1.30	6.07	− .15
7.44	− .32	4.78	1.25	6.6	− .17
7.94	− .41	4.96	.96	6.57	− .17
8.44	− .50	4.67	1.45	5.58	.19
8.92	− .59	4.76	1.30	5.86	− .04
9.38	− .67	4.76	1.29	5.89	− .06
9.83	− .75	4.78	1.25	6.0	− .12
10.26	− .83	4.81	1.20	5.32	.46
10.68	− .9	4.84	1.16	5.67	.10
11.08	− .97	4.84	1.16	5.74	.04
11.47	−1.04	4.87	1.11	5.98	− .11
11.85	−1.11	4.91	1.04	5.37	.40
12.22	−1.18	4.97	.94	5.73	.05
12.58	−1.24	5.00	.90	5.82	− .01
12.92	−1.30	5.05	.82	6.07	− .16
13.26	−1.36	5.12	72	5.54	.22
13.59	−1.42	5.2	.61	5.89	− .06
13.91	−1.48	5.26	.53	6.0	− .12
14.22	−1.53	5.34	.43	6.26	− .11

Appendix B *(con't.)*

Economy IV		Economy V		Economy VI	
% Unemployment	Rate of Inflation	% Unemployment	Rate of Inflation	% Unemployment	Rate of Inflation
U	*F*	*U*	*F*	*U*	*F*
5.39	.38	3.84	3.36	6.92	−.23
5.58	.18	8.26	−.47	3.34	4.85
6.7	−.19	7.34	−.31	6.93	−.23
6.14	−.09	4.12	2.64	5.73	.05
7.01	−.25	4.36	2.07	3.15	5.48
4.57	1.65	4.95	.98	7.01	−.25
5.24	.56	4.62	1.54	5.76	.03
4.44	1.92	4.68	1.44	3.00	6.72
5.74	.05	4.00	2.95	6.65	−.18
5.13	.71	4.70	1.40	5.75	.04
5.76	.03	3.85	3.3	4.34	2.13
4.64	1.51	4.08	2.75	3.00	7.98
4.86	1.12	4.09	2.72	3.99	2.96
3.00	6.0	4.12	2.65	7.82	−.39
3.41	4.62	4.19	2.47	6.69	−.19
3.00	8.92	4.34	2.14	3.00	7.87
3.00	17.82	4.32	2.17	3.00	8.49
3.00	24.57	4.47	1.86	3.00	23.08
3.00	40.64	4.59	1.61	3.00	95.65
3.00	47.71	4.60	1.58	3.00	236.71